

TABLE 9.—*Turbidities in an advancing Npc air mass, Dec. 14-16, 1931*

Lincoln	Madison	Washington
Dec. 14, $T=1.96_s$ Dec. 15, $T=2.13_s$ Dec. 16, $T=2.22_s$	Dec. 14, $T=1.94_s$	Dec. 15, $T=2.42_s$

The increase in  $T$  from 1.96 in the Midwest to 2.42 in Washington on the following day shows the rapid pollution of the Npc air as it travels eastward. Because of the subsidence inversion which is thought to exist in the Npc air, this acquired pollution is probably concentrated in a thin surface layer. At Lincoln the successive increases in  $T$  on the 14th, 15th, and 16th show how the turbidity is increased when the direct flow of Npc from the northwest is replaced by a flow from southerly quarters due to movement of the high pressure center eastward.

3. *Situation of October 16-21, 1931.*—A large body of Npp air covered a major portion of the continent on the 15th; on the night of the 15th-16th it invaded Madison, and on the morning of the 17th, Washington. The air mass stagnated, the anticyclonic center remaining over West Virginia from the 17th to the 21st. On the night of the 21st-22d, fresher Npp reached Washington. The values of  $T$  are given in table 10.

TABLE 10.—*Turbidities in an advancing Npp air mass, Oct. 16-21, 1931*

Lincoln	Madison	Washington
Oct. 15, $T=2.03_s$ 16, 1.98 <sub>s</sub> 17, 2.13 <sub>s</sub> 18, 2.43 <sub>s</sub> 19, 2.33 <sub>s</sub>	Oct. 16, $T=2.27_s$ 17, 1.87 <sub>s</sub> 19, 1.84 <sub>s</sub> 20, 3.49 <sub>s</sub>	Oct. 17, $T=2.14_s$ 19, 2.43 <sub>s</sub> 20, 2.24 <sub>s</sub> 22, 2.13 <sub>s</sub>

The Lincoln  $T$ 's show a gradual increase from about 2 on the 15th-16th, to about 2.4 on the 18th-19th, corresponding to the shifting of the wind on the 17th from the northwest, which brought in fresh Npp, to the south, bringing in older Npp. The high turbidity at Madison

on the 16th may be explained by local conditions since the morning observer reports smoke and a visibility of 8 miles with a northwest wind. The wind shifted into the south on the 19th and the older return air on the 20th shows a much larger value,  $T=3.49$ ; here, again, the observer reports smoke and a visibility of 8 miles with a south wind. The turbidity at Washington increases from 2.14 on the 17th, when the fresh Npp current came in, to 2.43 on the 19th, after the high had stagnated. The drop in  $T$  to 2.24 on the 20th, when conditions were practically unchanged cannot be explained from the available data. However, the decrease to 2.12 on the 22d is probably due to fresh Npp displacing the older Npp.

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## SOME WIND VELOCITY CORRELATIONS

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[Weather Bureau, Madison, Wis., Dec. 1934]

Two studies of wind velocity in as many relationships, employing the methods of correlation analysis, are reported in this paper:

1. *True versus indicated velocity.*—Among the assets of the meteorologist that a banker would classify as "slow" rather than frozen, are the data of wind velocity that were written down in the records before the reduction to true velocity commenced January 1, 1932. The precise relation between true velocity and indicated has been set forth in the papers by Marvin entitled "A Rational Theory of the Cup Anemometer" (*MONTHLY WEATHER REVIEW*, 60, 1932, pp. 43-57) and "Recent Advances in Anemometry" (*MONTHLY WEATHER REVIEW*, 62, 1934, pp. 115-120), where the lines that represent the functional relation show a pronounced curvature near the origin. In the present study, the observed results flow from the official conversion table in Instructions No. 14, 1931.

It is obvious that the conversion table just mentioned cannot be applied to monthly averages, inasmuch as the latter comprise a wide spectrum of different velocities,

each requiring a different correction. The object of this study is to discover the law of relationship of the monthly means of the indicated velocities to the means of the true velocities.

In preparing this paper the hourly wind movement for each of the 236,320 hours in the 27 years, 1905-31, was converted to true velocity by applying the official correction. The results were averaged and compared with the averages of the raw data. The help of eight students in the University of Wisconsin who made the conversions and averages, and of Messrs. Batz and Lorenz of the staff of the Madison Weather Bureau Office in checking the arithmetic, is gratefully acknowledged.

In the case of the three-cup anemometer, the official conversion table adds 1 mile to all indicated velocities from 0 to 16, no correction to 26, and subtracts about 12.5 percent from higher indicated velocities. The averages show a difference of precisely 1 mile at all velocities below 9 miles per hour, indicated (10 miles per hour true). Above those limits the few available cases

show a steady decrease of the correction at the rate of about 10 percent for each mile above 9. These relations can be expressed in equations:

$$Y = X + 1.0 \quad (X \leq 9.0)$$

$$Y = 0.9X + 1.85 \quad (X > 9.0)$$

In the case of the four-cup anemometer the bend of the curve is so slight that a straight line can be fitted to give very satisfactory conversion of indicated to true velocities in the averages by months. To show how closely the monthly averages fall on the curve, and how nearly straight the curve really is, straight lines have been fitted by the method of least squares to the averages for the 20 years, 1905-24 for each of the 12 months, and for all together, as well as for seasons of more and less wind. The results of these calculations are gathered in table 1.

TABLE 1

Month	Average velocity			Regression coefficient			
	4-cup	True	Difference	b	Angle	a	r
	1	2	3	4	5	6	7
January.....	10.57	10.43	-0.14	0.7802	37 58	2.18	0.9954
February.....	10.84	10.65	-.19	.7729	37 42	2.27	.9977
March.....	11.40	11.06	-.34	.7677	37 31	2.31	.9979
April.....	11.24	10.96	-.28	.7693	37 34	2.42	.9974
May.....	9.70	9.78	+.08	.7719	37 40	2.29	.9956
June.....	7.81	8.30	+.49	.8097	39 00	1.98	.9900
July.....	7.22	7.80	+.58	.8042	38 48	2.00	.9935
August.....	7.28	7.85	+.57	.8526	40 27	1.64	.9898
September.....	8.16	8.57	+.41	.7781	37 54	2.22	.9952
October.....	9.43	9.55	+.12	.7932	38 36	2.02	.9958
November.....	10.58	10.63	+.05	.7664	37 28	2.37	.9989
December.....	10.30	10.24	-.06	.7911	38 21	2.09	.9952
Year.....	9.57	9.64	+.07				
All months.....	9.56	9.65	+.09	.7826	38 03	2.17	.9994
September-May.....	10.27	10.21	-.06	.7754	37 47	2.25	.9984
June-August.....	7.44	7.98	+.54	.8205	39 22	1.88	.9921

The constants of the straight lines of best fit (Galton's lines of regression) are in columns 4 and 6 of table 1. From the last three lines of the table the following equations are derived:

$$Y = 0.7826X + 2.17 \quad (\text{All months})$$

$$Y = 0.7754X + 2.25 \quad (\text{September-May})$$

$$Y = 0.8205X + 1.88 \quad (\text{June-August})$$

Application of the first of these equations to the recorded means, for 26 years, gave "predicted" true velocities agreeing with the calculated values precisely in 70 percent of the cases, and differing no more than one-tenth of a mile in the remainder. Use of the second and third equations increased the number of coincidences to 75 percent while all the other differences remained exactly 0.1 mile. Other combinations were tried, without improving the result.

To show the closeness of the data to the same curve, the correlation coefficient, corrected for number of items, has been calculated, and is given in column 7. The values are phenomenally high, 0.99 to 1.00.

To show how slight is the turning of the curve in the part covered by the data, the angle of slope of each line of best fit is given in column 5. Another measure of the same thing is afforded by the values of  $a$ , the intercept on the  $Y$  axis, in column 6.

In the case of the four-cup anemometer, there is zero correction at 10.0 miles per hour, lower velocities are increased, and higher diminished. The effect on averages

is indicated in column 3. At the level of wind velocity prevailing at Madison, Wis., the annual average velocity is little changed by conversion from indicated to true.

The values of  $\bar{Y}$  from the equation for all months, are tabulated in table 2, for the benefit of anyone who wishes to test the results of this paper on data obtained elsewhere. Inasmuch as the comparison is independent of everything except the frequency distribution of wind velocities, comparable results should be obtained anywhere in the Central and Northern States.

TABLE 2.—Conversion of monthly mean indicated (4-cup anemometer) wind velocities to true velocities

	Indicated velocity (m. p. h.)										
	5	6	7	8	9	10	11	12	13	14	15
	True velocity										
0.0.....	6.1	6.9	7.6	8.4	9.2	10.0	10.8	11.6	12.3	13.1	13.9
0.1.....	6.2	6.9	7.7	8.5	9.3	10.1	10.9	11.6	12.4	13.2	14.0
0.2.....	6.2	7.0	7.8	8.6	9.4	10.2	10.9	11.7	12.5	13.3	14.1
0.3.....	6.3	7.1	7.9	8.7	9.4	10.2	11.0	11.8	12.6	13.4	14.2
0.4.....	6.4	7.2	8.0	8.7	9.5	10.3	11.1	11.9	12.7	13.4	14.3
0.5.....	6.5	7.3	8.0	8.8	9.6	10.4	11.2	12.0	12.7	13.5	14.4
0.6.....	6.6	7.3	8.1	8.9	9.7	10.5	11.2	12.0	12.8	13.6	14.5
0.7.....	6.6	7.4	8.2	9.0	9.8	10.5	11.3	12.1	12.9	13.7	14.6
0.8.....	6.7	7.5	8.3	9.1	9.8	10.6	11.4	12.2	13.0	13.8	14.7
0.9.....	6.8	7.6	8.4	9.1	9.9	10.7	11.5	12.3	13.0	13.8	14.8

2. *Influence of forest growth on wind velocity.*—The exposure of the anemometer at Madison, Wis. on the campus of the University of Wisconsin has been free from the changes ordinarily experienced at city Weather Bureau offices. The anemometer has been exposed on the same pole, and the only important changes in buildings were the erection of the Biology Building 500 feet away in 1910, and the burning of the dome on Bascom Hall in 1916.

In spite of the uniformity of the exposure, the records show a steady decrease of average wind velocity, and of the frequency of strong winds. The annual wind movement has decreased 510 miles per annum, and the annual total is now more than 15,000 miles less than it was in 1904 when the anemometer was set up. The number of days with maximum velocities has fallen off at the rate of 1.14 days per annum.

The only reason that I can think of for this change is the growth of the trees that form a thick forest on the slope down to Lake Mendota north of the station. The tops of the highest trees are now as high as the anemometer, and the general level of the top of the forest is only about 10 feet below the anemometer. This general level of the top of the forest has risen, I estimate, some 10 or 12 feet since I first saw it in 1908.

TABLE 3.—Secular trend of wind velocity at Madison, Wis.

Month	Average velocity, (4-cup)	Trend (miles per hour)	Percent	Standard deviation
January.....	10.4	-.081	-.078	0.83
February.....	10.7	-.115	-.107	.84
March.....	11.3	-.024	-.21	1.14
April.....	11.2	-.073	-.65	.93
May.....	9.7	-.093	-.96	.71
June.....	7.9	-.033	-.42	.88
July.....	7.2	-.038	-.53	.55
August.....	7.2	-.050	-.69	.48
September.....	8.1	-.036	-.44	.50
October.....	9.3	-.098	-1.05	.78
November.....	10.7	-.045	-.42	1.11
December.....	10.3	-.019	-.18	.72
Year.....	9.5	-.057	-.60	.26

If the decrease of wind velocity is due to forest growth it is natural to expect the rate of decrease to be greater in summer, when the trees are in leaf, than in winter, when they are bare. In order to test this, secular trend lines were obtained by fitting a straight line to the data for each month and for the year by least square methods. The results are given in table 3.

The average trend in percentage is 0.68 for the 6-months May–October, when the trees are in leaf, 0.55 for November–April when bare. The coefficient of correlation of the annual wind velocity with the years is  $-0.84$ . The monthly data are much more variable and give smaller coefficients of correlation.

## RECORD NOVEMBER FOG PRECEDING PHENOMENAL WINTER OF 1933–34 IN THE PACIFIC NORTHWEST

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[Weather Bureau, Portland, Oregon, June 1934]

The outstanding winter of 1933–34 was preceded, in November, by the greatest amount of dense fog ever recorded in the Pacific Northwest. Dense fog occurred at every airway and first-order station in the states of Oregon and Washington. The number of days with dense fog ranged from 3 at La Grande, Oreg., to 25 at Wolf Creek, Oreg.; the number of hours with dense fog during the month ranged from 5 at La Grande, to 217 at Eugene, Oreg. (See table 1.)

In a search for the cause of this unusual amount of fog, many interesting facts were discovered. The first is the relation between pressure distribution and the formation of fog. Using the Portland 4-hourly airway maps as a

Portland, Baker, and Roseburg. The 5 a. m. pressure reports were arbitrarily chosen because they were closely associated with fog conditions. The pressures were tabulated according to station and day of month; then those for days on which dense fog occurred were segregated, and the percent of possible days with fog was determined for each pressure. The results are shown on graph B, figure 1.

It will be noted that 88.2 percent of the dense fog occurred at pressures of 30.2 inches or above. This leads directly to a major contributing cause—the pressure over the Northwest was 0.15 to 0.27 inch above normal for the month of November, and thus was well within the limits favorable to formation of fog.

A review of storm tracks during the month will, in part, explain the unusually high pressure. On the 2nd of November a storm moved west to east through central Washington. From that time until November 27, no storms moved in through the Pacific Northwest. However, 9 storms did move in just north of Prince George, through a belt some 600 to 900 miles north-northeast of Portland, Oreg.; this distance seems to be ideal for fog formation in Washington and Oregon.

November 1933 eclipsed all previous years of record with a collective total of 58 days with dense fog at the stations of Seattle, Spokane, Portland, Baker, and Roseburg. These stations were selected because their length of record facilitates comparison with other years having excessive fog. Second in rank is November 1905, with a collective total of 43 days with dense fog; storm tracks were all north of Prince George, British Columbia, except one on the last day of the month. Then follows the year 1917, with a November collective total of 41 days with dense fog; all storms moved in north of Prince George. Next in rank are the years of 1923, 1922, and 1907; for these years similar conditions prevailed, except that a storm track through the Northwest in the opening days of November becomes more prevalent. In a study of other years with large collective totals, it becomes evident that the collective total of days with dense fog for the Northwest decreases in proportion to the number of storms moving inland south of Prince George.

A storm moving in through the Northwest very early in November, or late in October, is favorable to production of fog. The immediate reason is evident, as radiation fog is common in a stagnant, saturated air-mass from the Pacific Ocean. When such an air-mass is allowed to stagnate, fog sets in quickly and soon becomes widespread. Stagnation, however, depends on a new series (1) of Lows starting immediately through the channel mentioned, just north of Prince George. This new series effectively shuts off the usual outburst of dry continental air following the eastward movement of a storm. Such an outburst of dry, cold air through the Northwest would quickly wash the stagnant, saturated

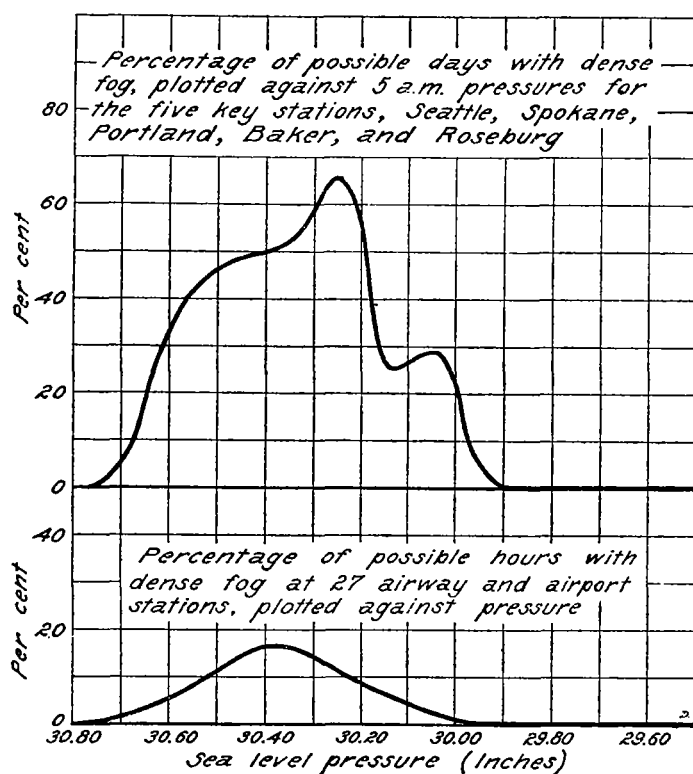


FIGURE 1.—Fog and pressure graphs for Pacific-Northwest, November 1933.

basis, all reports of dense fog in Oregon, Washington, southwestern Idaho, and northern California were tabulated according to the barometric pressure at the time when fog occurred. (See table 2.) This analysis was carried further by tabulating all hourly pressure reports, with or without dense fog, at the 27 airway and first-order stations. The percentage of possible hours with dense fog was then determined; the results are shown on graph A, figure 1.

The relation between pressure and days with dense fog was developed for the five key stations, Seattle, Spokane,